$\Lambda(1520)$ at finite density

M. M. Kaskulov and E. Oset

Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, Aptd. 22085, 46071 Valencia, Spain

Abstract. We study the decay channels of the $\Lambda(1520)$ in a nuclear medium and find a sizable change - of the order of factor five - of the width of this hyperon at normal nuclear matter density. The mass shift of the $\Lambda(1520)$ is moderate.

The change of resonance properties in the nuclear medium is a field that captures permanent attention, and basic symmetries can be tested through medium modification of particle properties. The later is particularly interesting for resonances which are not the genuine three quark states surviving in the large-N_c limit of QCD, but can be generated dynamically using the effective degrees of freedom and effective forces constrained by the symmetry pattern underlying the QCD.

The $\Lambda(1520)$ is an example of such dynamic state which can be generated from the *s*-wave interaction of the decuplet of baryons with the octet of pseudoscalar mesons using the leading order chiral Lagrangian in combination with resummation schemes which respect the unitarity in coupled channels [1, 2]. In particular, the $\Lambda(1520)$ appears basically as a quasibound state of the $\pi\Sigma^*(1385)$ system.

The small free width of the $\Lambda(1520)$ of $\simeq 15.6$ MeV comes from the decay into $\bar{K}N$ and $\pi\Sigma$ channels, but the decay into $\pi\Sigma^*(1385)$ is forbidden for the nominal mass of the $\Sigma^*(1385)$. The coupling of the $\Lambda(1520)$ to $\bar{K}N$ and $\pi\Sigma$ makes the picture of the $\Lambda(1520)$ more elaborate, with $\pi\Sigma^*(1385)$ being a very important component but with also sizable admixtures of $\bar{K}N$ and $\pi\Sigma$ [3].

At finite baryonic density, the decay of the $\Lambda(1520)$ bears resemblance to the one of the $\Delta(1232)$ in the nuclear medium. The Δ decays into πN and the π gets renormalized in the medium by exciting ph and Δh components, as a consequence of which the Δ is renormalized and its pion (photon) induced excitation in nuclei incorporates now the mechanisms of pion (photon) absorption in the medium. In the present case, the $\Lambda(1520)$ decay into $\pi\Sigma^*(1385)$, only allowed through the $\Sigma^*(1385)$ width, gets drastically modified when the π is allowed to excite ph and Δh components in the nucleus, since automatically the phase space for the decay into $ph\Sigma^*(1385)$ gets tremendously increased. This fact, together with the large coupling of the $\Lambda(1520)$ to the $\pi\Sigma^*(1385)$ channel predicted by the chiral unitary approach, leads to a very large width of the $\Lambda(1520)$ in nuclei. Similar nuclear effects will modify the $\pi\Sigma$ decay channel and the $\bar{K}N$ will be analogously modified when the $\bar{K}$ is allowed to excite hyperon-hole excitations. All these channels lead to a considerable increase of the width of the $\Lambda(1520)$ in the nucleus.

In the description of the $\Lambda(1520)$ properties in the nuclear medium we closely follow

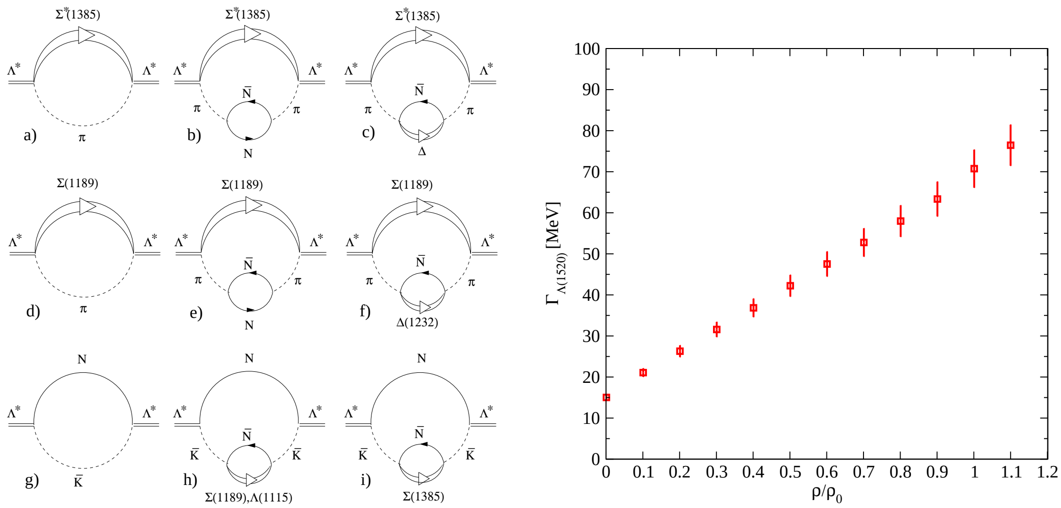

FIGURE 1. Left panel: The renormalization of the $\Lambda(1520)$ in the nuclear medium. Right panel: Values with theoretical uncertainties for the width of the $\Lambda(1520)$ at rest in the medium, including the free width, as function of the nuclear matter density ρ/ρ_0 (a).

the formalism developed in Ref. [4] (see also Ref. [5] for related discussions and comments in Ref. [4] about the approximation made in Ref. [5]). Here we briefly summarize the main results of that studies.

In the nuclear medium the $\Lambda(1520)$ gets renormalized through the conventional d-wave decay channels including $\Lambda(1520) \to \bar{K}N$ and $\Lambda(1520) \to \pi\Sigma$ which accounts for practically all of the $\Lambda(1520)$ free width. In addition in Ref. [4] as a novel element the s-wave decay $\Lambda(1520) \to \pi\Sigma^*(1385)$ has been considered which is forbidden in the free space for the nominal masses of the $\Lambda(1520)$ and $\Sigma^*(1385)$ but opens in the nuclear medium.

The model diagrams which describe the renormalization of the $\Lambda(1520)$ in the nuclear medium are shown in Fig. 1 (left panel). The in-medium propagation of pions in the loops is affected by the excitation of the $p-hole$ and $\Delta(1232)-hole$ states and in the antikaon $\bar{K}$ case by the excitation of the all relevant hyperon-hole states. The intermediate baryons in the loops are also dressed with respect to their own decay channels properly renormalized in the nuclear medium. The later includes the dressing by means of the phenomenological optical potentials which account for the nuclear binding corrections, Pauli blocking for the nucleons and short-range correlations in the p-wave transitions induced by the strong repulsive forces at short inter-baryon distances of the Landau-Migdal type. In Fig. 1 (right panel) we show the model prediction for the width Γ_{Λ^*} of the $\Lambda(1520)$ at rest and at the nominal pole position as a function of the nuclear matter density ρ/ρ_0 where $\rho_0 = 0.16~\mathrm{fm}^{-3}$ is the normal nuclear density. The error bar reflects the theoretical uncertainties due to the choice of the momentum cut off in the d-wave loops. As one can see the model predicts a spectacular change of the width of the $\Lambda(1520)$ in the nuclear medium which gets increased by factor ~ 5 at normal nuclear matter densities. The corresponding mass shift of the $\Lambda(1520)$ is $\delta m \simeq -30$ MeV only.

The problem of the in-medium modification of the $\Lambda(1520)$ in the $\pi\Sigma^*(1385)$ channel is mainly reduced to the proper description of the properties of pions and $\Sigma^*(1385)$ at

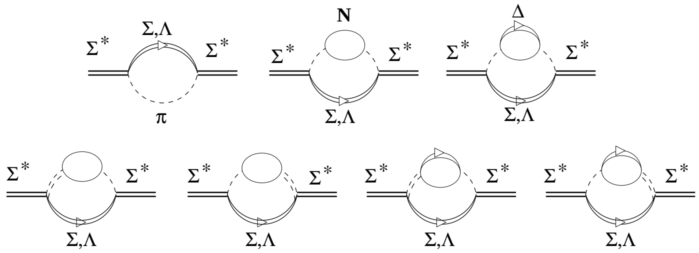

FIGURE 2. In-medium renormalization of the $\Sigma^*(1385)$ in the $\pi\Sigma + \pi\Lambda$ channels. The last four diagrams account for the short-range correlations.

finite nuclear density. The renormalization scheme which we employ for the $\Sigma^*(1385)$ is essentially the same as in the previous case except for the p-wave nature of the hadronic $\Sigma^*(1385)$ decay. This implies some peculiarities, for instance, the proper treatment of short range correlations. The typical diagrams describing the in-medium selfenergy of $\Sigma^*(1385)$ are shown in Fig. 2. The later account for the $\Sigma^*(1385) \to \pi\Sigma + \pi\Lambda$ decay channels. Similar diagrams appear then considering the $\bar{K}N$ decay channel where $\bar{K}$ gets renormalized by coupling to the all relevant hyperon-hole excitations. All together, we find an increase of the width of the $\Sigma^*(1385)$ by the factor $\sim 2 \div 3$ at normal nuclear matter density with respect to the free width $\Gamma_{free} \simeq 35$ MeV. The in-medium change of the mass of the $\Sigma(1385)$ is very moderate $\delta m \simeq -40$ MeV.

The spectacular change in the $\Lambda(1520)$ width should be easily verified experimentally. To facilitate this work we have performed calculations of the A dependence of the $\Lambda(1520)$ produced in the $\gamma A \to K^+\Lambda(1520)A'$ and $pA \to p'K^+\Lambda(1520)A'$ reactions where we find a sizable A dependence linked to the modification of the $\Lambda(1520)$ width in the medium [6].

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